INSTRUCTION BOOK

for

MODEL 353
DC DIGITAL VOLTMETER

STARTING WITH SERIAL No. 301

BALLANTINE LABORATORIES, INC.
BOONTON, NEW JERSEY

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WARRANTY

Each Ballantine Laboratories, Inc. instrument, or part thereof is warranted to be free from defects in material and workmanship. Ballantine Laboratories, Inc. obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except vacuum tubes and batteries, which shall within one year after shipment to the original purchaser prove upon Ballantine Laboratories, Inc. examination to have become defective.

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Fig. 1. Ballantine Model 353 DC Digital Voltmeter

Fig. 2. Model 800 Rack Mounting System for Ballantine Modular Instruments

1. GENERAL INFORMATION

1.1 Features

Ballantine Laboratories offers a new approach to accurate measurement of dc voltages with the Model 353 Digital Voltmeter. Novel electro-mechanical design* allows measurement of laboratory accuracy to be made with a small, lightweight, economical instrument. Speed and ease of operation suggest the Model 353 for production testing as well as laboratory use.

A servo-driven, three-digit counter is used as an automatic readout to combine virtues of both analog and digital voltmeters. Fast, clear readings are provided by the illuminated, in-line readout with automatic decimal point and range indication. The rotating counter wheels follow slow signal variations and allow interpolation of the last digit, thus avoiding the ± 1 digit restriction of fully digitized displays. A front-panel indicator warns of exceeded range or incorrect polarity.

The accuracy and resolution of the basic instrument is increased tenfold (from three to four digits) by special "expand" circuitry.* The most significant digit is read with the instrument operating in its normal three-digit mode (with .02% resolution). This number is then manually dialed in and the instrument automatically rebalances in the four-digit, expand mode (with .002% resolution, see Fig. 3). Operation of the counter-readout is inhibited during these switching operations to minimize mechanical noise and wear.

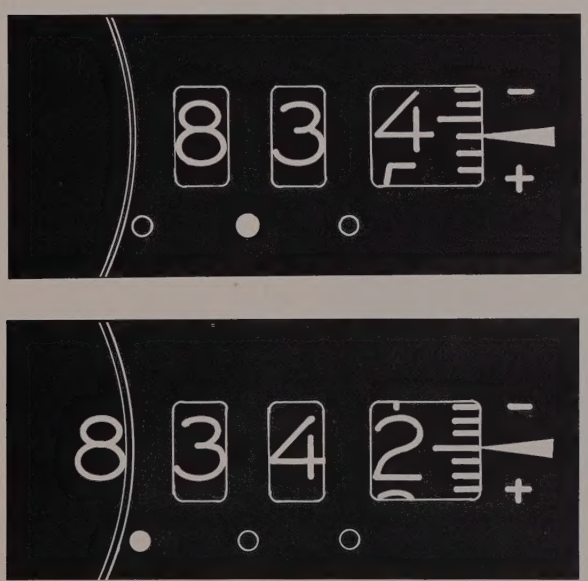


Fig. 3. Indication in Normal and Expand Modes

*Pat. applied for

For production use, an auxiliary switch, either foot operated (Model 1355) or activated by other test equipment, may be connected to the socket on the rear of the instrument. A normally closed connection will hold a reading until a new measurement is to be made, while a normally open connection will allow continuous measurements until closed. A manual hold switch is also provided on the front panel.

Simple circuitry, sturdy construction, and all-silicon active devices insure reliability and long life for the Model 353. Conservative operation of all electrical components further assures long life and outstanding performance. Should maintenance be required, the printed circuit board and all switches are easily accessible.

The Model 353 is packaged in the compact, Ballantine ½ rack modular case. Normally supplied as a portable instrument, it can be rack mounted in minutes using the Model 800 Rack Mounting Kit. The Model 353 is compatible, without modification, with Hewlett-Packard Modular enclosures.

A summary of important features of the Model 353 includes:

- Laboratory accuracy with production ease and speed
- Self balancing and direct reading, in-line digital readout
- Economy and reliability through simple circuitry
- Small and light
- High resolution
- Wide voltage range
- Temperature compensated, aged, zener reference for long term stability
- High, constant input impedance
- Three-terminal input for floating measurements
- Overload proof
- Indication of overrange and inverted polarity

1.2 Some Applications of the Model 353

For high or low accuracy laboratory measurements

As a working standard

High resolution monitoring

Fast, fatigue-free production line tests of dc voltages

Regulation, accuracy and stability tests on power supplies

Linearity checks on accelerometers, gyros, and converters

As a readout device for analog computers

Incoming inspection tests

Voltage, temperature-coefficient and stability checks of zener diodes

Calibration checks of moving coil indicators

As a high-resolution readout in parallel with the moving coil indicator of analog meters

1.3 Technical Characteristics (per ASA C39.6)*

A. Accuracy

1. At reference conditions after one hour warm-up (see paragraph 1.3 H):
   EXPAND MODE ±0.02% rdg ±0.01% fs
   NORMAL MODE ±0.15% fs
2. At rated operating conditions (see 1.3 G):
   EXPAND ±0.04% rdg ±0.01% fs
   NORMAL ±0.15% fs

B. Stability

1. Long term:
   Within rated accuracy for 6 months.
2. Line voltage effect (for ±10% change within 105 to 125 V):
   EXPAND less than 0.004% change in indication
   NORMAL less than 0.04% change in indication
3. Temperature coefficient:
   < ±0.001%/°C

C. Resolution

EXPAND 0.002% fs
NORMAL 0.02% fs

D. Response Time

1. Incremental (time for a one digit change to be nulled with rated accuracy):
   < 1 second
2. Step (maximum nulling time for a step input change within any range):
   < 5 seconds

E. Input Characteristics

1. Full scale voltage ranges:
   EXPAND 1.1 V, 11 V, 110 V, 1.1 kV with > 0.25% overranging
   NORMAL 100 mV, 1 V, 10 V, 100 V, 1 kV with 2.5% overranging
2. Input resistance at null:
   10 megohms for all ranges and modes
3. Input capacitance:
   Below 40 pF for ranges above 1 V
   Below 140 pF on lowest ranges
4. Maximum input current at null:
   100 μA at 1000 V
5. Maximum input current off null:
   100 μA at 1000 V
6. Extreme source resistance (for 0.05% loading error
   5000 Ω
7. Normal Mode interference ratio:
   > 2,000 (66 dB) at 60 Hz
   > 1,000 (60 dB) at 120 Hz

F. Isolation Parameters

1. Common Mode interference ratio:
   > 1,000,000 (120 dB) for dc and ac except
   > 10,000 (80 dB) at 60, 120 and 180 Hz
2. Common Mode short-circuit current:
   < 3.0 μA at 600 V dc

3 Common Mode impedance:
> 200 MΩ || 0.02 μF

G. Rated Operating Conditions

1. Ambient conditions:
   Temperature 12°C to 40°C
   Relative humidity 0 to 98%
   Barometric pressure 575 to 800 mm Hg
2. Operating power:
   105 - 125 V, 50 - 60 Hz, 16 W
3. Position:
   Any
4. Input limits:
   Sustained full scale input for an indefinite time
   Maximum overload of 1.3 kV on highest range and 500 V on lowest range
5. Case to signal-ground breakdown voltage:
   > 600 V peak

H. Reference Conditions (where different from rated)

1. Ambient conditions:
   Temperature 23 ±1°C
   Relative humidity 10 to 55%
2. Operating power:
   114 - 120 V, 59.5 - 60.5 Hz

I. Recommended Calibration Period:
Every 6 months or 1000 operating hours

J. Mechanical Specifications:
External dimensions: 7.8 W, 6.1 H, 10.3 D (inches)
Weight: 7.7 pounds
Shipping weight: 12 pounds
Color: Light gray panel, charcoal gray case

*American Standards Association requirements for dc digital voltmeters.

2. OPERATION

2.1 Function of Controls

INPUT switch

OFF disconnects power

\+ instrument indicates positive dc voltages

− instrument indicates negative dc voltages

RANGE switch

Selects full scale voltage indication

MODE switch

NORMAL instrument indicates three digits with 2.5% overrange to four

EXPAND switch selects first digit of measured voltage to give four or five digit indication with > 0.25% over-ranging

HOLD-READ-HOLD switch

Disables servo-drive with either momentary or latching action

ZERO ADJ

Allows zero indication to be checked with input terminals shorted

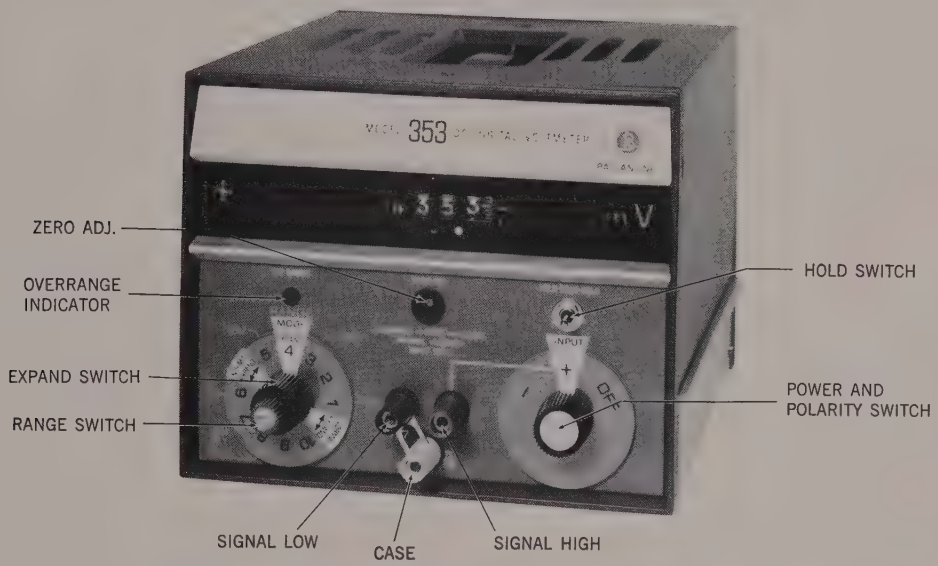


Fig. 4a. Controls, Indicators and Connectors, Front

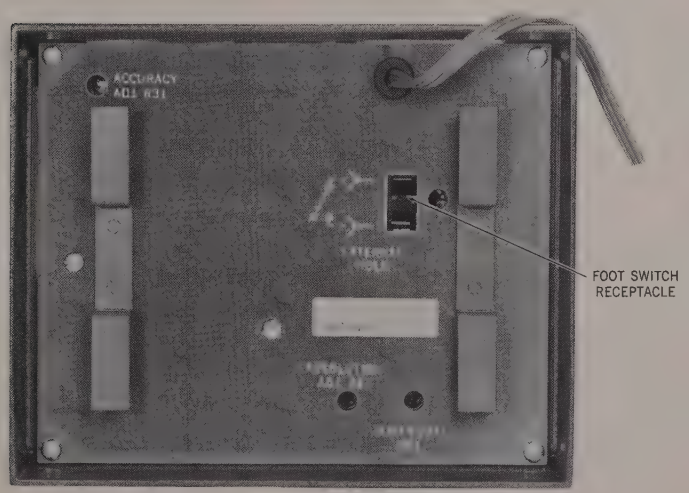


Fig. 4b. Controls, Indicators and Connectors, Rear

2.2 Connectors

Input

Red binding for signal input, black for signal ground, white for case ground

External hold

Appliance type receptacle for connection of external hold switch, such as the Model 1355. DO NOT GROUND EITHER CONTACT.

2.3 Power Connection

The instrument is supplied for operation on 105 - 125 V, 50 - 60 Hz power as indicated on the decal on the rear panel. If operation on a 230 V line is desired, remove the instrument case and the back panel and proceed as follows:

The appropriate connections are located on the main printed circuit board, below the line fuse, F1. Remove the gray wire on the board from its connection with the black/red wire. Resolder the gray wire to the black wire below the right-hand end of the fuse in the vacant terminal provided (Fig. 10). Replace Fuse F1 with a 0.15 A Slo-Blo unit.

2.4 Starting

Plug the instrument into the line using an adapter where grounded, three-terminal outlets are not available. Turn the MODE switch to NORMAL, the RANGE switch to 1 kV and the INPUT switch to + or −. The polarity, units and counter illumination should all be on.

2.4.1 Warmup Period

The instrument is usable immediately. In less than five minutes, readings will be well within rated accuracy. For highest accuracy, or after long or humid storage, allow one hour warmup. Since the instrument is fully transistorized, no special care is required for air-cooling. However, the instrument should not be operated close to other apparatus capable of creating high ambient temperatures. The maximum rated ambient temperature is 40°C. However, the instrument may be operated at 55°C or stored at 70°C.

After such storage the 1000 hour accuracy tests should be made (Sec. 4).

2.4.2 Zero Adjustment

After warmup and before measurements are made, check the instrument zeroing by shorting or disconnecting the input terminals, with red RANGE set to 1 kV and MODE set to NORMAL. Using the front-panel screwdriver adjustment, zero the readout with INPUT set to +. Now set INPUT to −. If the instrument reads off zero, adjust the ZERO EQUALIZER control on the rear of the instrument. Set this to split the difference in zeroing between + and − settings of the INPUT switch and re-zero with ZERO ADJ. This may have to be performed several times to achieve the best (±0.2 digit) zeroing agreement between + and − INPUT settings.

2.5 DC Voltage Measurement

Set the red RANGE switch to 1 kV, and the MODE switch to NORMAL. Connect the input (red) and signal ground (black) terminals to the dc source being measured. With the HOLD switch in READ position, reduce the red RANGE setting until three digits (with 2.5% overrange to four) are indicated. The OFF-RANGE indicator will be on until the instrument has balanced itself. This is the NORMAL mode of operation of the Model 353. To utilize the full accuracy and resolution of the instrument, place it in the EXPAND mode by dialing in the most significant (leftmost) digit as read from the NORMAL mode indication. (A red 1 in NORMAL is dialed in as a 10). The Model 353 will now indicate four or five digits with 0.25% overranging. Accuracy will be as specified in 1.3.

If the input to the instrument becomes greater than the range selected in either mode, the display will run up to its stop and the OFF-RANGE lamp will remain on. In NORMAL mode, correct by switching to a higher range. In EXPAND, first try dialing in larger first-digits. If this fails, return to NORMAL mode and find the correct range again. The instrument will not be damaged if left in an overloaded state since the circuits are inherently self-limiting. An input of the wrong polarity will cause the OFF-RANGE lamp to turn on and the display will run down past zero to about 997. In EXPAND mode this is accompanied by the indication of two red numbers to the left of the counter. Correct by changing the INPUT switch polarity to start again in NORMAL mode.

In EXPAND mode, an input less than the digit dialed in will also result in double red indication. Reduce the EXPAND setting, or return to NORMAL to correct for this.

NOTE: Never use a reading when the off-range lamp is on, or when the hold switch is retaining an earlier indication.

2.6 Possible Sources of Error

2.6.1 Common operational errors result from: incorrect polarity setting, overranged in NORMAL or EXPAND, underranged in EXPAND, zeroing misadjusted, internal or external hold improperly activated, fuse open, or power not applied.

2.6.2 Loading error caused by the finite input resistance and/or capacitance of the instrument. Source resistances of 5 kΩ or less require no correction within the specified accuracy. Input capacitance must be considered when measuring dc levels in ac circuits susceptible to detuning or capacitive loading.

2.6.3 External fields or ground currents of power line frequency, if extremely large, can result in normal or common mode pickup. While ac rejection ratios are high (1.3), the signal and case grounds should be separated and short or twisted input leads used whenever possible.

2.6.4 Thermal voltages result when dissimilar metals are used for connecting leads. A small temperature difference between the wire junctions can thus create errors in low-level measurements. Uniform temperature or copper leads throughout will reduce such errors to acceptable levels.

2.6.5 When making measurements requiring the counter to begin transfer of all the digit wheels (i.e. from 999 to 1000), a small error can occur. This error is well within the specified accuracy, but should be considered when high resolution measurements are to be made. In such cases avoid this transfer region.

2.7 The Effect of AC Input Components

The input filter of the Model 353 will usually be sufficient to avoid errors in the presence of ac ripple (1.3.E7). If large ac components at 60 or 120 Hz are present, an additional low-pass filter may be connected at the input terminals, but loading error must be considered (2.6.2).

2.8 High Voltage Measurement

If potentials above 100 V are to be measured, select the highest range before connecting the input signal. For floating measurements at high voltage, avoid contact with the back panel screws, some of which are at signal ground. Be sure that the case is grounded separately. For measurements above 1000 V, an external voltage divider, such as the Ballantine Model 1320, must be used.

2.9 Differential DC Voltage Measurement

Signal and case grounds are separated on the Model 353 and internal shielding is used to reduce common mode interference effects. The maximum specified common mode voltage is 600 V peak.

2.10 DC Current Measurement

Ballantine Series 600 Precision Shunt Resistors can be plugged directly into the input terminals of the Model 353. Measurement of current from 10 μA to 10 A is easily made.

2.11 Input Impedance

At null, the input resistance is 10 MΩ on all ranges in both modes. Off null, the input resistance differs from this only on the 0.1 V normal and 1 V expanded ranges where it is 650 kΩ, increasing to 10 MΩ as a null is approached.

2.12 Reading Retention

The three-position (HOLD - READ - HOLD) toggle switch on the front panel permanently or momentarily holds a reading by disabling the servo motor drive. The display remains free to turn, however, and the stored indication may change slightly under conditions of heavy vibration. The switch should be used whenever the instrument is running unattended or when readings are not being made. This reduces mechanical wear throughout the servo-system. Be sure to move the switch to READ before using a new indication.

The panel-switch, or the optional Model 1355 Footswitch, allows a series of like measurements or stability tests to be made with greater convenience. If an external switch is connected to the EXTERNAL HOLD receptacle at the rear of the instrument, the panel switch should be in READ position. The external switch should be capable of carrying 250 mA at 10 V dc. A normally closed switch will provide "press to read" ability. This is usually the most convenient connection, and is the best way of lengthening readout life.

2.13 Line Voltage Variation

The instrument will operate properly on 100 - 130 V, 45 - 75 Hz lines. No degradation of specified accuracy should occur between 105 and 125 V. The instrument should not be used below 100 V or above 130 V due to excessive jitter induced in the servo-system.

2.14 Use of a Converter for AC Voltage Measurement

An AC to DC Converter such as the Ballantine Model 710A may be used with the Model 353 operating in NORMAL mode. However, the conversion accuracy and noise will affect the overall measurement accuracy and resolution, and must not be neglected. Since the Model 353 has a resolution of better than .002% in EXPAND mode, even small converter fluctuations will cause the readout to jitter. To avoid unnecessary wear, the HOLD switch should be used between measurements, even with high quality converters.

3. CIRCUIT DESCRIPTION

The Model 353 is a self-nulling analog-servo voltmeter measuring dc levels between 0 and 100 mV.

A simplified diagram appears in Figure 5, while a complete schematic and parts list are provided at the end of this instruction book. The following sections discuss the functions of each portion of the instrument.

3.1 Input Attenuator

A dc voltage applied to the input terminals is fed to a precision resistive attenuator, where it is divided down by decades to the nominal 0.1 V level required by the servo-loop. Each range above 0.1 V is separately adjustable for easy calibration (see Section 4.3.2). All resistors are wirewound except for R1 which is metal film. Temperature stability is assured by compensation of R1 with thermistor R2.

On the 0.1 V range in NORMAL mode, the input signal is fed without attenuation to the servo-loop.

The same occurs on the 1 V range in EXPAND mode. The EXPAND mode is only available on the four higher ranges since it requires attenuation to be reduced by one decade in each range (3.4).

3.2 Input Filter and Protection

A low-pass, notch filter feeds the servo-amplifier from the input attenuator. Maximum low frequency rejection occurs in the 50 - 60 Hz region, but signals of high frequency are also attenuated. A small discharge lamp V6 and resistor R20 provide protection from extreme overloading, while diodes CR1 and CR2 protect the contacts of chopper G1.

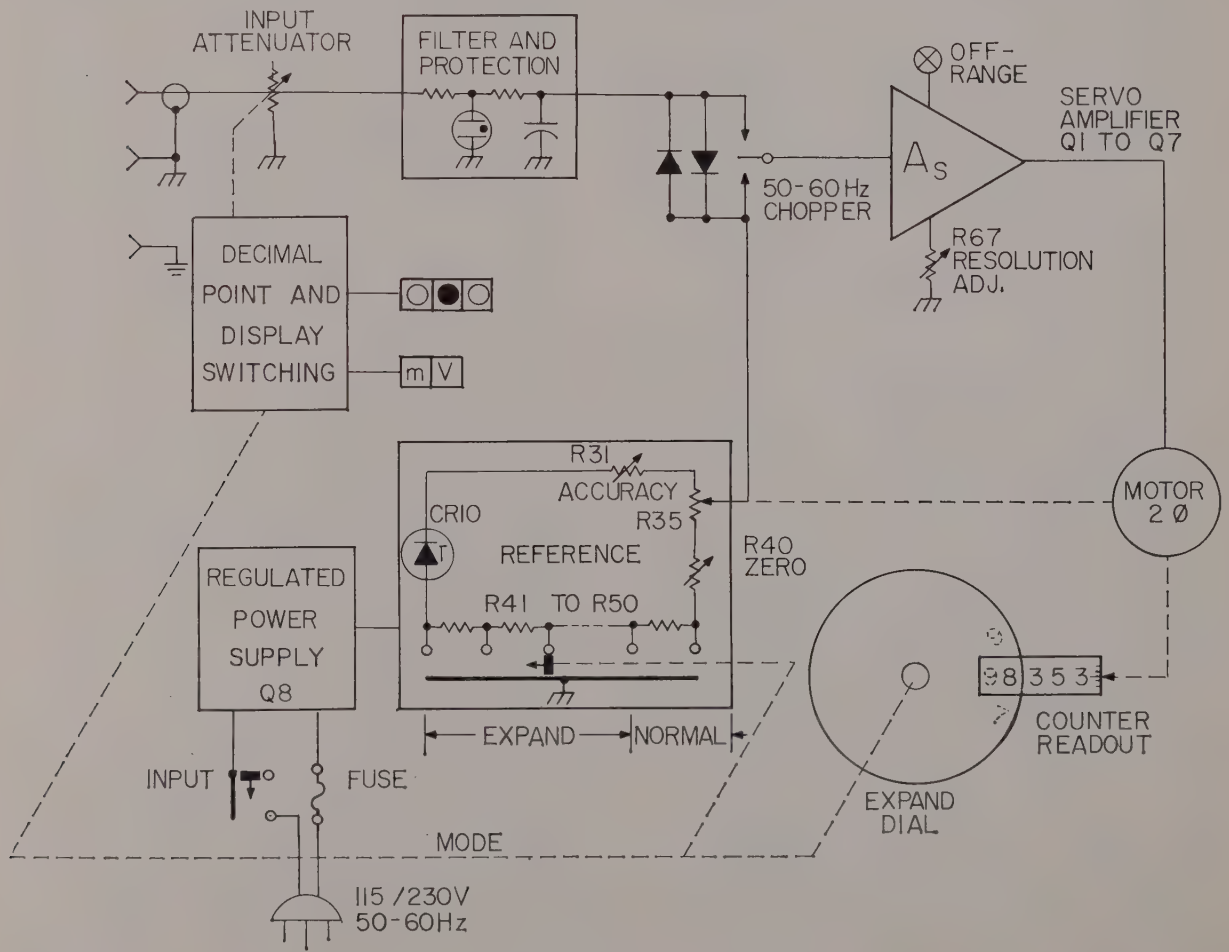


Fig. 5. Simplified Circuit Diagram

3.3 The Servo-Loop

The attenuated, filtered dc input is compared with a variable dc reference by a line-driven chopper G1.

The output of the chopper is thus a square wave of line frequency whose amplitude is proportional to the difference between the dc reference and the attenuated dc input. In addition, this square wave is either in phase or 180 degrees out of phase with the line waveform depending on whether the reference is above or below the attenuated input level. The amplitude information is used to adjust the reference until no chopper output exists. The phase information determines in which direction the reference should be adjusted. To achieve this adjustment (nulling) with high resolution, a high gain (80 dB) ac amplifier is used. The output of this amplifier drives one winding of a two-phase induction motor which, in turn, drives the reference potentiometer R35 and the counter readout. The second motor phase is referenced to the line along with the chopper drive. Thus, the phase of the amplified chopper signal determines the direction in which the motor will turn to achieve a null. A phasing adjustment R87 is provided to insure that the motor will run well in either direction. This adjustment is not critical and normally should not require attention (5.4).

3.4 The DC Reference

The heart of the reference section is a temperature-compensated zener diode (CR10) which is fed by a constant current source, including Q8, CR11 and CR9 which temperature compensates Q8.

A pre-regulating zener diode (CR12) further stabilizes the supply. The reference voltage is fed through a reversing switch (S2) to allow either positive or negative inputs to be measured. The reference level (approx. 9 V) is then divided down to 100 mV and applied to the 10-turn, motor-driven potentiometer R35. Several adjustments are provided: for zeroing (R40), for setting the 100 mV level (R36), for full scale accuracy (R31). A small bias voltage derived from diodes CR7 and CR13 is also applied to the reference at R38. This allows correction for small thermal voltages which would otherwise prevent zeroing in + and − modes simultaneously. R84 (ZERO EQUALIZER) thus allows the zero to be set and held for both positive and negative measurements.

In the EXPAND mode the reference potentiometer is biased in 100 mV steps above its nominal 100 mV level and the input attenuation is reduced by one decade. This allows measurements at ten times normal resolution to be made around a pre-selected level. R41 through R50 provide this ability and are chosen to give biasing steps corresponding to the most significant digit of a measured voltage.

3.5 The Servo-Amplifier

Q1 through Q7 comprise a high-gain transistor amplifier whose gain determines the resolution, but not the accuracy, of the Model 353. R67 controls local feedback for Q4 and thus provides a resolution adjustment. The first stage (Q1 - Q2) uses a cascaded emitter-follower to achieve high input impedance, while Q3 - Q5 give the necessary gain. The output driver-power stage (Q6 - Q7) operates directly into the inductive load of one phase of the servo-motor. Capacitors C25 and C26 neutralize this loading. If the instrument is off null, a large ac signal will exist across R75, lighting indicator I1. The HOLD switch shorts the collector of Q7 to B+, thus disabling the motor.

3.6 Motor and Readout

A three-digit turns counter is driven directly by the servo motor which also drives the 10-turn reference potentiometer through a 10.3:1 gear reduction. The counter indication is thus directly proportional to the potentiometer setting, and the gear ratio provides a 3% overrange capability. The motor is a two-phase, 24 V induction unit with one winding connected to the power transformer. The second winding is driven through a reversing switch by the servo-amplifier. When the input switch (S2) is turned from + to −, both the motor drive winding and the dc reference are reversed.

3.7 The Power Supply

The power supply consists of three separate sections each fed from its own transformer winding.

The dc reference is driven from a full-wave rectifier and filter (CR16, CR17, C33).

The B+ supply for the servo-amplifier is similarly obtained (CR14, CR15, C34). CR13 carries the return current to the supply, thus providing approximately −0.7 V bias for the ZERO EQUALIZER control R84.

The reference phase of the servo motor and the chopper coil are driven from a 17 V balanced winding. The phase of the chopper voltage can be varied with R87, which forms one leg of a phasing bridge completed by the two transformer winding halves and C35, C36.

The neon lamps for decimal point and units indication are supplied from the 220 V tap of the primary transformer winding. This portion of the Model 353 should be treated with care to avoid shock.

4. MAINTENANCE

The model 353 is designed for extended, reliable service. All components are conservatively operated and the use of silicon active devices further assures long life. Periodic checks (every 6 months or 1000 hours) should be made, however, to guarantee high accuracy and maximum reliability.

4.1 Recommended Maintenance

Every 1000 hours of operation or every 6 months, the dc accuracy and resolution, input attenuator decading, linearity, and motor-counter assembly should be tested. If maintenance equipment of the required accuracy is not available, the instrument may be returned to Ballantine Laboratories for recalibration (Sec. 6).

4.2 Necessary Maintenance Equipment

A stable dc voltage source, adjustable between 100 mV and 1000 V, is required. If the accuracy of this source is not ±.01% of indication or better, or if its source impedance is greater than 1 kΩ, then a ±.01% of indication dc digital voltmeter must be used to monitor the calibrating signal. For normal in-circuit voltage tests and troubleshooting, a general purpose instrument such as the Ballantine Model 345 is recommended.

4.3 Periodic Tests (1000 hours or 6 months)

4.3.1 DC Accuracy and Resolution

Allow the instrument to operate for 30 minutes or more. Check the zero adjustment (2.4.2) and reset if necessary. Connect a 100 mV ±0.01% dc voltage to the input. Set the INPUT switch to +, the MODE switch to NORMAL, the RANGE switch to 0.1 V, and the HOLD switch to READ. The instrument should indicate 100.0 ±0.1. Approach 100 mV, as indicated by the source, from above and below and observe the difference in the two Model 353 readings. If the difference exceeds 0.1%, then the resolution adjustment (R67) must be reset. Do not set R67 unnecessarily high since this will cause excessive jitter in the readout. If the average of the two readings differs by more than 0.1% from 100 mV, then adjust the accuracy control (R31). These adjustments are all accessible through the rear panel and require no disassembly of the instrument. If the 100 mV level cannot be set with the accuracy control, return it to its mid-position, remove the instrument case and adjust R36 (Fig. 11). This is a small potentiometer mounted on the fourth deck of the MODE switch. In cases of extreme misadjustment, both R31 and R36 may need resetting.

For final setting of R31, switch RANGE to 1 V and MODE to EXPAND 9. Apply 1 V ±0.01% and adjust R31 (Accuracy) to indicate 1000.0 ±0.1 mV.

If a large change is made in either R31 or R36, check the 100 mV NORMAL range again and reset R36 if necessary.

4.3.2 Attenuator

To check the RANGE attenuator, first check the dc accuracy as above, then switch RANGE to 10 V and MODE to EXPAND 9. Remove the instrument cover and adjust R3 (10 k, first trimmer potentiometer on the MODE switch) to give an indication of 10.000 ±0.001 V with 10 V ±0.01% input. Switch RANGE to 100 V and 1 kV and similarly adjust R5 (1 k) and R7 (100) with 100 V and 1000 V ±0.01% input. Remaining at 1000 V, switch MODE to NORMAL and adjust R9 (10) to give 1000 ±1 V. Replace the instrument cover and check again in the 1 V EXPAND 10 configuration tc be sure that the accuracy control R31 is correctly set. This completes the basic calibration procedure.

4.3.3 Linearity

Check the zero adjustment and verify the full-scale accuracy of the 1 V range as in 4.3.1; then reduce the input voltage in 0.1 V steps and record the Model 353 indication in both modes. These readings should be within specified accuracy (1.3 A) plus or minus the error in the calibration equipment. Within any normal or expanded range, the basic linearity is determined by the reference potentiometer R35. The linearity of the expand string (R41-R50) governs the tracking of the expand digit settings.

4.3.4 Mechanical Lubrication

The motor-counter assembly must run freely. If the mechanism becomes noisy or sluggish, lubrication may be required (see also 5.9). Remove the case and bottom plate of the instrument. Tip the instrument up on its front panel. Apply only two drops of non-gumming oil (such as Ore-Lube LT-10) to the main counter bearings (Figs. 7, 12). Units with serial numbers above 300 have ball-bearing counters and should require little attention.

5. SERVICE AND TROUBLESHOOTING

In case of malfunction, the Model 353 may be serviced by the user, provided skilled personnel and recommended equipment are available. The simple procedures outlined here are presented only as an aid. If proper facilities are not available, or if trouble persists, the instrument should be returned to Ballantine Laboratories for service and recalibration. The instrument must then be preceded by a letter stating the symptoms and nature of the trouble (see Section 6 for shipping instructions).

WARNING: When the instrument is operated without the cover or back panel, danger of shock exists. EXERCISE CARE. The highest voltage is 230 V ac.

5.1 Line Voltage Conversion

Conversion to the 230 V power lines is outlined in Section 2.3 and on the schematic diagram at the end of this book.

5.2 Fuse Replacement

Remove the instrument cover and snap the fuse out of its clip on the printed circuit board (Fig. 10). For 115 V, use a 0.3 A Slo-Blo ¼" x 1¼" fuse. For 230 V, use a 0.15 A unit. Determine the cause of fuse failure before operating the instrument again.

5.3 Voltage Check

When an operating fault occurs, it is often useful to determine if voltages measured in the circuit are normal.

Using a general-purpose VTVM (Section 4.2) check ac and dc voltages at the points noted on the schematic. Pay particular attention to those which are more than ±15% away from the schematic values and attempt to isolate one section of the instrument as the faulty one. Ultimate determination of the fault may require removal and testing of a transistor or component (5.8).

5.4 Chopper Replacement and Phase Adjustment

5.4.1 The Chopper Used in the Model 353 is a hermetically-sealed, plug-in type which is not a critical part. Its replacement, however, requires rechecking the zero and resolution adjustments (Sections 2.4.2, 4.3.1).

A defective chopper may be indicated by:

No reading

Excessive jitter

Large discrepancies between + and − readings

Slow-running display

Poor resolution

5.4.2 Poor Resolution in the Readout may be caused by a severe misadjustment in R87, which controls the relative phase of the chopper drive voltage. Remove the case and the rear shield panel. Turn the instrument on and rotate the counter gear by hand a fraction of a revolution while adjusting R87 for maximum restoring torque in both directions.

5.5 Escutcheon Plate Removal

Servicing the motor-counter assembly or the various indicator lamps requires removal of the outer front panel (escutcheon plate).

Switch the instrument off and remove its cover. Remove all three knobs. Unplug the 9-pin connector adjacent to the motor. Remove the two #4 flat-head screws from the top corners of the front frame.

Remove the two #4 binder-head screws from the bottom of the front frame. The escutcheon can now be pressed forward and out of the front frame.

5.6 Attenuator Repair

The input attenuator resistors are adjustable in each range (Sec. 4.3.2) and should only require repair in the event of damage. In such case the instrument should be returned to Ballantine Laboratories for repair (Sec. 6).

If the instrument is allowed to rest unused for a long period of time or is stored in a sulphuric atmosphere, the RANGE and MODE selectors may become intermittent. Usually several operations of each switch will correct this. If not, the contacts may be carefully cleaned with alcohol or a commercial contact cleaner.

5.7 Indicating Lamp Replacement

Remove the escutcheon plate according to Section 5.5.

The over-range bulb, if burned out, may cause a change in operation speed and resolution. Replace with a GE #291 or equivalent. Be sure that the cardboard sleeve remains on the socket.

The counter illumination lamps should be replaced with Tung-Sol #2309 or equivalent. The +, −, m, V and decimal point lamps are all NE2H neon glow units. Their life should be extremely long. Replacement is straightforward except for the decimal point units which may require removal of the decimal point board.

5.8 Transistor Replacement

All transistors may be replaced with standard units except Q1, Q2 and Q3, which have been selected for low noise and leakage. These units should be obtained directly from Ballantine Laboratories. Transistor failures should occur rarely, so be sure that the fault is correctly located before resorting to replacement.

5.9 Motor-Counter Repair

The motor-counter assembly, being a mechanically moving part, is subject to wear under continuous use. Frequent use of the HOLD switch or the Model 1355 Foot-switch in "press to read" connection will lengthen the life of the counter and the 10-turn potentiometer. For replacement, the entire assembly can be obtained from Ballantine Laboratories. When ordering, state the model and serial numbers of the instrument. A parts list appears in Section 8. The assembly need not be removed for replacement of the potentiometer, gear or motor stator. A sluggish readout may require lubrication. Sec. 4.3.4.

5.9.1 Removing the Motor-Counter Assembly

Remove the escutcheon plate (Sec. 5.5). Record the position of the MODE switch and the EXPAND dial. Remove the center screw from the rear of the EXPAND dial and remove the dial. Unsolder all five motor leads and the three potentiometer leads after recording their locations. Remove the three, cushioned nylon screws supporting the assembly (Fig. 11) noting the location of associated spacers. Tilt the assembly to gain access to the two screws holding the decimal point board. The assembly may now be removed from the instrument. Reassembly is just the reverse of this procedure, except that the cushioned support screws must not be overly tightened, and the EXPAND dial and decimal point lamps must be carefully aligned with the counter mask cutout (Fig. 6).

Four 2-56 screws allow the mask to be removed for access to the counter bearings. When reassembling, be sure that the counter wheels are free to turn and do not scrape the EXPAND dial mask. Alignment of the expand digits with the counter digits is accomplished by turning the chain drive wheel on the MODE switch.

5.9.2 Replacing the 10-Turn Potentiometer

Remove the instrument cover and turn the gear drive until the counter reads 000. Remove the gear and hub from the potentiometer shaft by loosening the two Allen-head set-screws holding the hub to the shaft (Fig. 7). Loosen the nut on the potentiometer, unsolder the four leads and record their position. Remove the potentiometer.

To replace the potentiometer, reverse the above procedure, resoldering the leads in the order: blue, green, white, from the rear of the potentiometer toward the bushing. Turn the potentiometer fully counter-clockwise and set the counter to 997. Carefully reinstall the gear.

Be sure the running parts move freely, and that the counter can turn up to at least 1025. A little free-play (lash) between the gears is desirable.

5.10 Rack Mounting

The Model 353 can be transferred from portable use to a standard Ballantine Model 800 Rack or an HP Modular Enclosure without physical modification. The supporting struts (bails) must, however, be folded back flush with the bottom of the case. Be sure that these are not so distorted as to short any internal parts of the instrument.

TROUBLESHOOTING CHART

Symptom	Possible Cause	Sections
Uncorrectable error between + zero and − zero	Chopper C30, 31 defective	5.4
Creeping indication, over-range lamp on	High ac input ripple	2.7
No indication	Fuse Hold actuated Wrong polarity Chopper	5.2 2.6 5.4
Error in all ranges and modes	R31 or R36 shifted Reference off	4.3.1
Error on low part of range	Zero misadjusted	2.4.2
Error or jitter at specific points on each range	R35, 10-turn potentiometer defective	5.9.2
Noisy, jittery readings	R67, resolution too high Noisy chopper Q1, Q2, Q3, R35, CR5 defective Counter needs lubrication	4.3.1 5.4 5.8, 5.9.2 4.3.4
Sluggish readout	Resolution too low Phasing misadjusted Mechanical trouble, stator misaligned, gears too tight	4.3.1 3.3, 5.4.2 4.3.4, 5.9
Drifting indication	Chopper, no reference	5.4
Error on specific ranges	Shifted or misadjusted attenuator	4.3.2
Shorted signal and case grounds	C40 defective Motor mounts defective	 5.9.1
No indication change with input	Hold actuated Open motor winding	2.6.1 3.6

6. SHIPPING INSTRUCTIONS

If it should be necessary to return the instrument to Ballantine Laboratories, Inc., make certain that at least four inches of padding material surrounds the instrument to prevent damage during shipment. Ship via REA Express, motor truck, or air freight, to

Ballantine Laboratories, Inc.
90 Fanny Road
Boonton, New Jersey

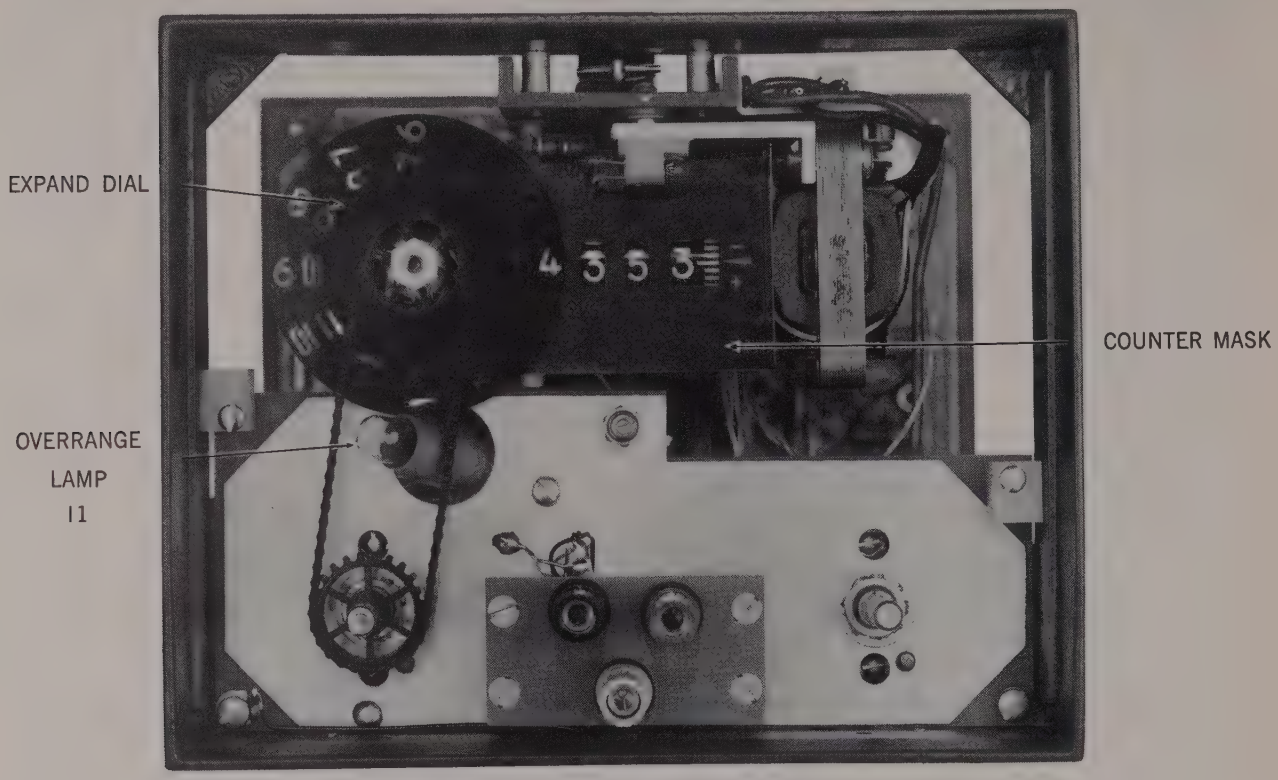


Fig. 6. Front View with Escutcheon Removed

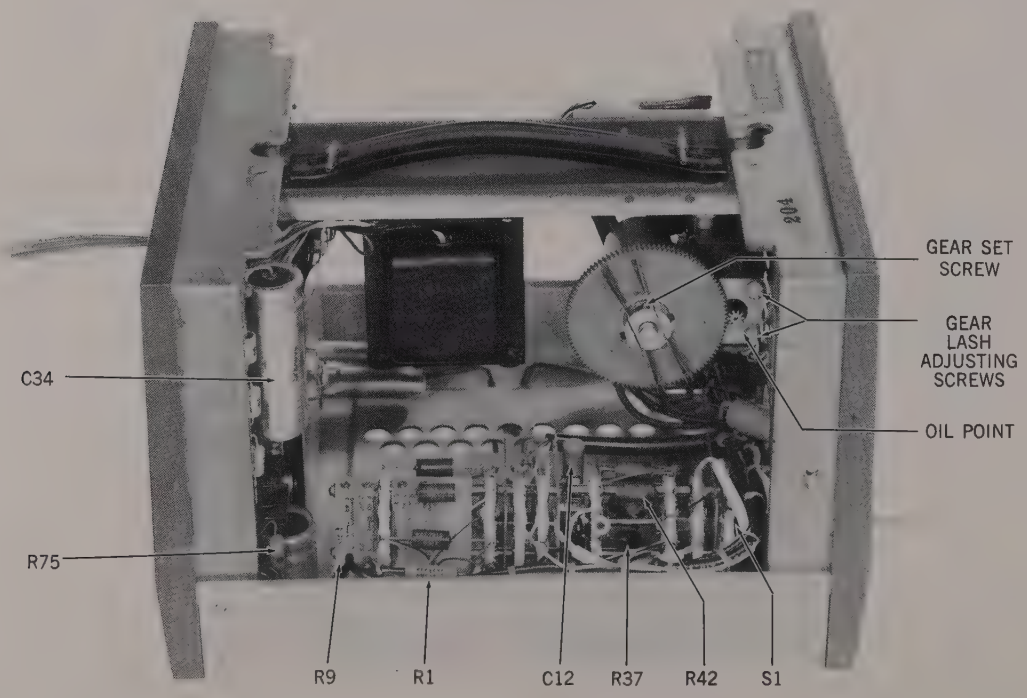


Fig. 7. Left Side View with Case Removed

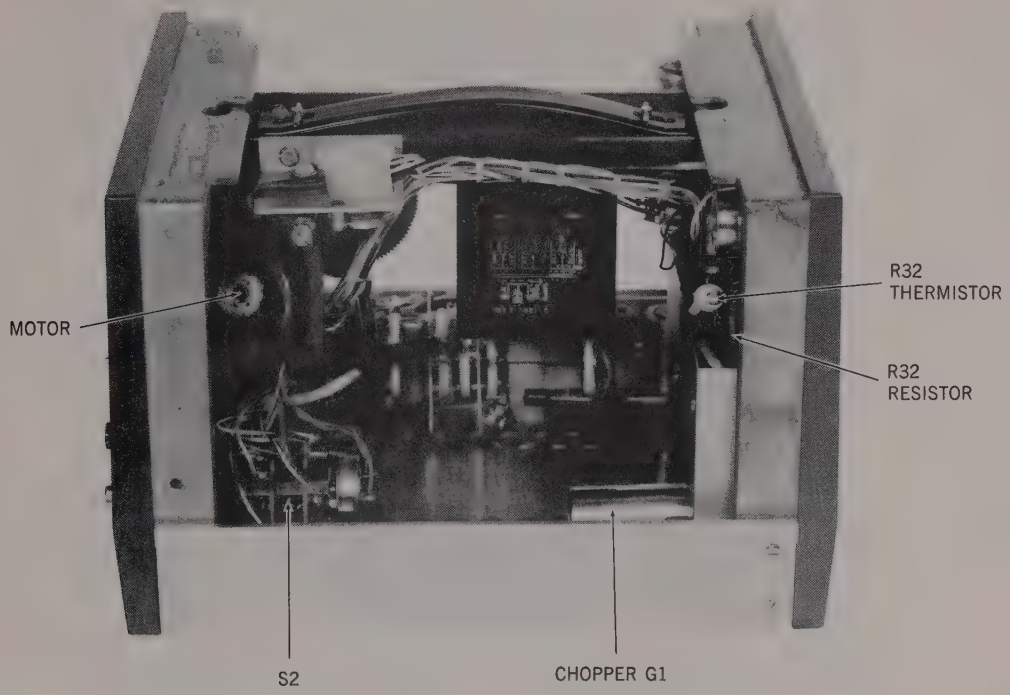


Fig. 8. Right Side View with Case Removed

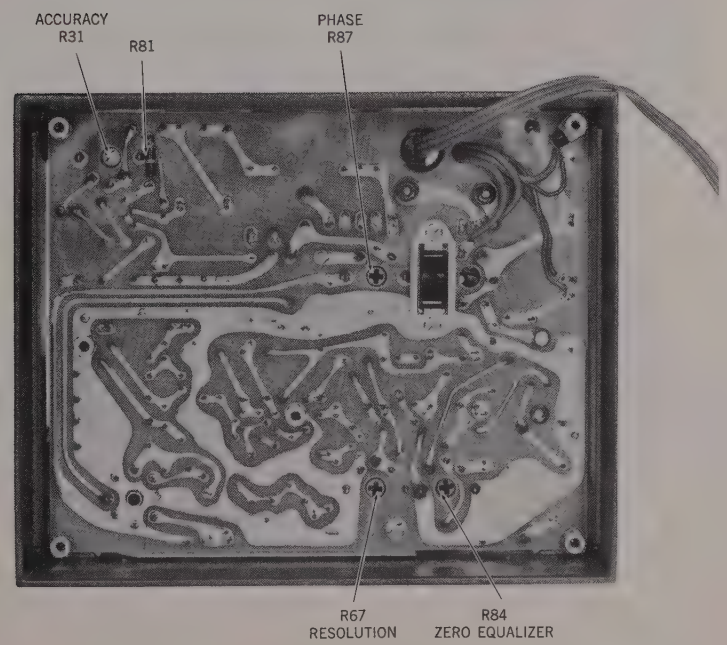


Fig. 9. Rear View with Shield Panel Removed

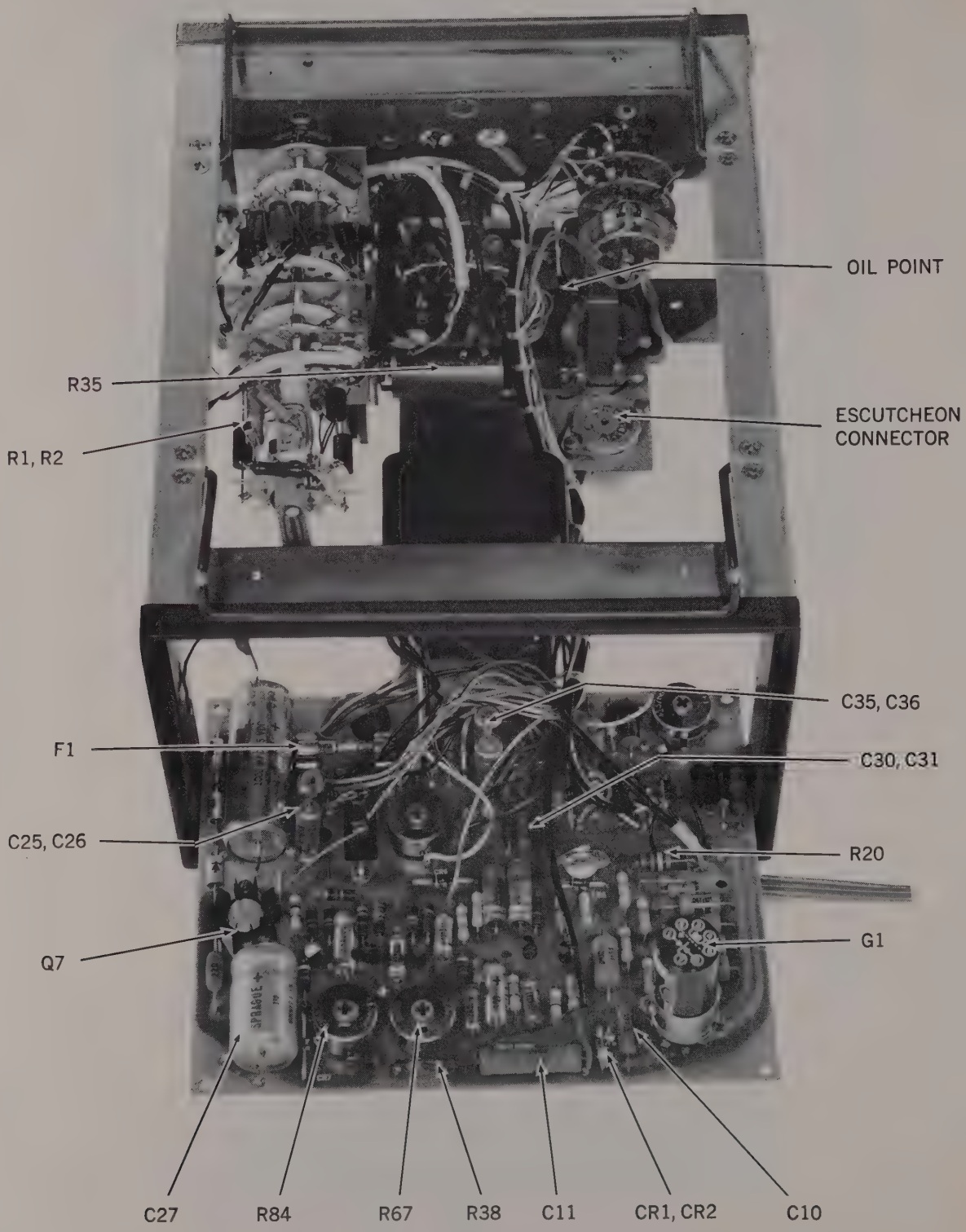


Fig. 10. Circuit Board Folded Out of Instrument

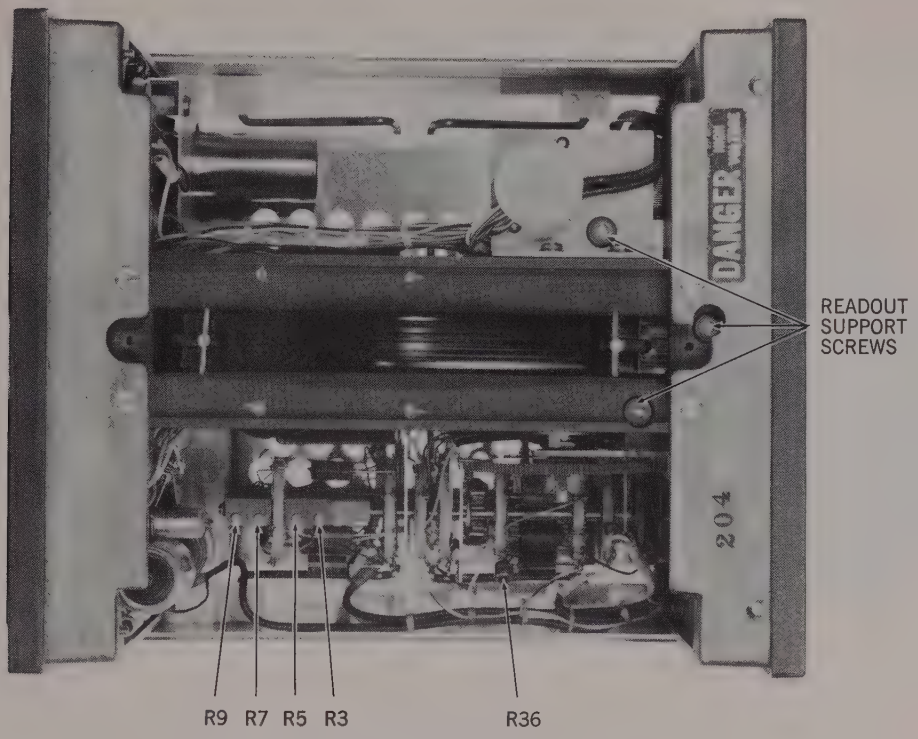


Fig. 11. Top View with Case Removed

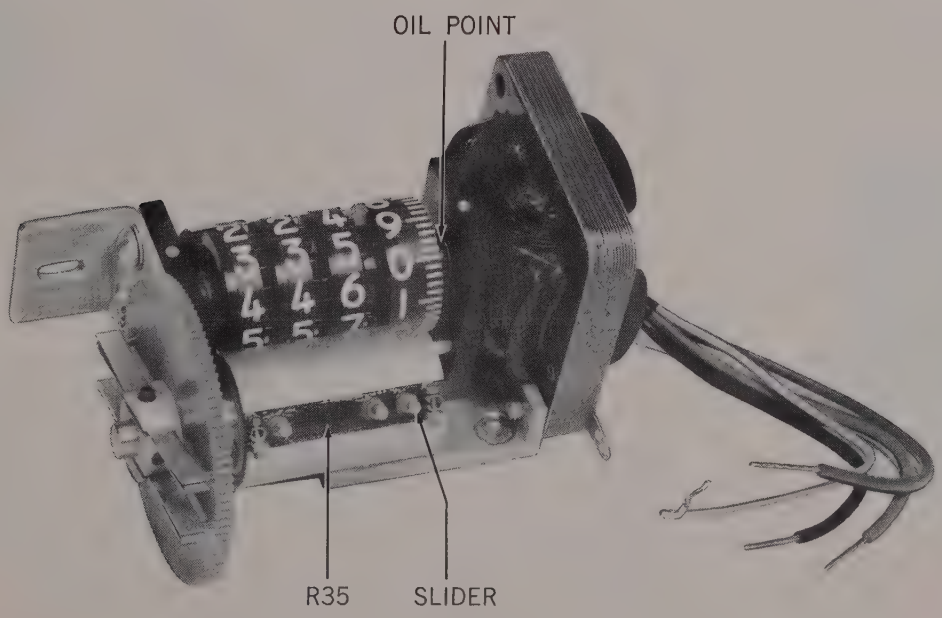
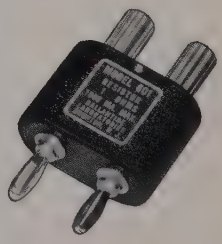
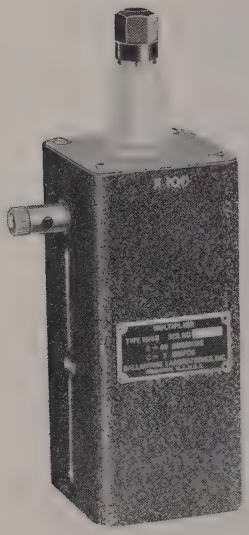


Fig. 12. Readout Assembly

Model 1355 Foot Switch



Series 600 Shunt Resistor



Model 1320 High Voltage Divider

Fig. 13. Optional Accessories for Model 353

7. REPLACEMENT PARTS LIST

REFER TO MODEL 353 SCHEMATIC, DWG. ME-3270 N

B. L. Part No.	Circuit Symbol	Capacitors	Manufacturer
8101	C1	0.047 μF, 10%, 200 V, Type 192P47392	Sprague
2795	C2	2700 pF, 10%, 200 V, Type 192P27292	Sprague
2796	C3	1500 pF, 10%, 200 V, Type 192P15292	Sprague
8101	C4	0.047 μF, 10%, 200 V, Type 192P47392	Sprague
2394	C5	0.1 μF, 5%, 200 V, Type 192P10452	Sprague
2394	C6	0.1 μF, 5%, 200 V, Type 192P10452	Sprague
2365	C10	0.01 μF, 5%, 200 V, Type 192P	Sprague
8126	C11	.47 μF, 80 V, Type 192P4749R8	Sprague
8126	C12	.47 μF, 80 V, Type 192P4749R8	Sprague
2394	C15	0.1 μF, 5%, 200 V, Type 192P10452	Sprague
7847	C16	10 μF, 16 V, Type C426AR/E10	Amperex
7835	C17	25 μF, 25 V, Type C426AR/F25	Amperex
2796	C18	1500 pF, 10%, 200 V, Type 192P15292	Sprague
7814	C19	1 μF, 12 V, Type 30D105G012AA4	Sprague
7814	C20	1 μF, 12 V, Type 30D105G012AA4	Sprague
2086	C21	25 μF, 12 V, Type 30D256G012BB4	Sprague
7814	C22	1 μF, 12 V, Type 30D105G012AA4	Sprague
7835	C23	25 μF, 25 V, Type C426AR/F25	Amperex
7835	C24	25 μF, 25 V, Type C426AR/F25	Amperex
7845	C25	80 μF, 25 V, Type C426AR/F80	Amperex
7845	C26	80 μF, 25 V, Type C426AR/F80	Amperex
7833	C27	1000 μF, 16 V, Type C437AR/E1000	Amperex
2785	C30	6.8 μF, 35 V, Type 150D	Sprague
2785	C31	6.8 μF, 35 V, Type 150D	Sprague
2796	C32	1500 pF, 10%, 200 V, Type 192P15292	Sprague
7812	C33	50 μF, 50 V, Type 30D506G050DH4	Sprague
2070	C34	1000 μF, −10% +75%, 25 V, Type 39D108G025GL4	Sprague
7828	C35	50 μF, 85 VDC, Type C426AR/F50	Amperex
7828	C36	50 μF, 85 VDC, Type C426AR/F50	Amperex
2594	C40	0.015 μF, 10%, 1000 V, Type CCD-153	Arco
		Resistors	
7212	R1	9,040,000 ohms, ±0.5%, Type PME70, Selected	Ballantine
1156	*R2	10,000 ohms, Type 41D2, Thermistor	Victory Engineering
6862	R3	10,000 ohms, ±20%, Type 75L R 10K	Beckman-Helipot
6195	R4	900,000 ohms, 0.25%, Type 7010	R.C.L.
6863	R5	1,000 ohms, ±20%, Type 75L R 1K	Beckman-Helipot
6196	R6	90,000 ohms, 0.25%, Type 7010	R.C.L.
6864	R7	100 ohms, ±20%, Type 75L R100	Beckman-Helipot
6197	R8	9,000 ohms, 0.25%, Type 7010	R.C.L.
6865	R9	10 ohms, ±30%, Type 75L R10	Beckman-Helipot
6198	R10	1,000 ohms, 0.25%, Type 7010	R.C.L.

* In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 353 SCHEMATIC, DWG. ME-3270A N

B. L. Part No.	Circuit Symbol	Resistors	Manufacturer
8002	R11	100,000 ohms, 10%, Type CB	Allen-Bradley
6055	R12	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
6055	R13	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
6055	R14	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
8002	R15	100,000 ohms, 10%, Type CB	Allen-Bradley
1281	R20	180,000 ohms, 5%, Type GB	Allen-Bradley
2649	R21	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
2649	R22	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
2649	R23	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
2649	R24	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
1071	R25	47 ohms, 10%, Type EB	Allen-Bradley
6861	R31	200 ohms, ±10%, Type 115	CTS
1160	*R32	25 ohms, Type 13E3, Thermistor	Victory Engineering
7237	*R33	2,200 ohms, 1%, Type N-20	Corning
1882	R34	36,800 ohms, 0.25%, Type 7010	R.C.L.
6855	R35	10,000 ohms, ±3%, Type 7216R10KL.05	Beckman-Helipot
6866	R36	10 ohms, Type 62P R10	Beckman-Helipot
6188	R37	538 ohms, 0.25%, Type P10	Shallcross
1784	R38	0.45 ohms, 10%, Special	Ballantine
8450	R39	5 ohms, 1%, Type P10	Shallcross
6857	R40	100 ohms, 20%, Type G	Allen-Bradley
6194	R41 (1)	495.3 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R42 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R43 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R44 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R45 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R46 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R47 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R48 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R49 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
6193	R50 (1)	500 ohms, 0.005%, Type 7010, Selected	Ballantine
2648	R55	470,000 ohms, 5%, Type E009AB/B 470K	Amperex
2648	R56	470,000 ohms, 5%, Type E009AB/B 470K	Amperex
6055	R57	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
6055	R58	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
6056	R59	51,000 ohms, 5%, Type E009AB/B 51K	Amperex
6059	R60	10,000 ohms, 5%, Type E009AB/B 10K	Amperex
1054	R61	2,000 ohms, 5%, Type EB	Allen-Bradley
1120	R62	4,700,000 ohms, 5%, Type EB	Allen-Bradley
6057	R63	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
6057	R64	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
1110	R65	2,400,000 ohms, 5%, Type EB	Allen-Bradley
1039	R66	22,000 ohms, 5%, Type EB	Allen-Bradley

(1) Resistors R41, R42, R43, R44, R45, R46, R47, R48, R49, R50 are part of a matched set and must be purchased as Set No. 1557.

*In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 353 SCHEMATIC, DWG. ME-3270A N

B. L. Part No.	Circuit Symbol	Resistors	Manufacturer
6859	R67	4,000 ohms, ±20%, Type 115	CTS
1018	R68	360,000 ohms, 5%, Type EB	Allen-Bradley
1089	R69	3,300 ohms, 5%, Type EB	Allen-Bradley
1039	R70	22,000 ohms, 5%, Type EB	Allen-Bradley
6059	R71	10,000 ohms, 5%, Type E009AB/B 10K	Amperex
1063	R72	300 ohms, 5%, Type EB	Allen-Bradley
1067	R73	150 ohms, 5%, Type EB	Allen-Bradley
1062	R74	390 ohms, 5%, Type EB	Allen-Bradley
1739	R75	22 ohms, 5%, Type 151E	Sprague
8464	R80	1,100 ohms, 0.25%, Type VA	Shallcross
1106	*R81	68 ohms, 10%, Type EB	Allen-Bradley
7237	R82	2,200 ohms, 1%, Type N-20	Corning
6199	R83	1,000 ohms, 0.25%, Type P10	Shallcross
6861	R84	200 ohms, ±10%, Type 115	CTS
1135	*R85	910 ohms, 5%, Type EB	Allen-Bradley
1101	*R86	15 ohms, 5%, Type EB	Allen-Bradley
6861	R87	200 ohms, ±10%, Type 115	CTS
8002	R88	100,000 ohms, 10%, Type CB	Allen-Bradley
8465	R89	10 ohms, 10%, Type RH5	Dale

Other Components

7920	CR1	Diode, Type 1N4148	General Electric
7920	CR2	Diode, Type 1N4148	General Electric
7910	CR5	Diode, Zener, Type 1N957B, 6.8 V ±5%, Selected	Ballantine
7912	CR6	Diode, Zener, Type 1N961B, 10 V ±5%	Hughes
7920	CR7	Diode, Type 1N4148	General Electric
7920	CR9	Diode, Type 1N4148	General Electric
7923	CR10	Diode, Zener, Type 1N938, 9 V ±5%, Selected	Ballantine
7911	CR11	Diode, Zener, Type 1N936, 8.55 V to 9.45 V, Selected	Ballantine
7922	CR12	Diode, Zener, Type 1N970B, 24 V ±5%	Hughes
7921	CR13	Rectifier, Silicon, Type 36591	RCA
7921	CR14	Rectifier, Silicon, Type 36591	RCA
7921	CR15	Rectifier, Silicon, Type 36591	RCA
7921	CR16	Rectifier, Silicon, Type 36591	RCA
7921	CR17	Rectifier, Silicon, Type 36591	RCA
2803	F1	Fuse, 0.3 A, Type 3AG-0.3, Slo-Blo, for 115 V operation	Littelfuse
or 2809	F1	Fuse, 0.15 A, Type 3AG-0.15, Slo-Blo, for 230 V opert'n	Littelfuse
3084	G1	Chopper, Type M3	Airpax
3486	I1	Overrange Light, Type 291	General Electric
3494	I2	Illumination Light, #2309	Tung-Sol
3494	I3	Illumination Light, #2309	Tung-Sol
3494	I4	Illumination Light, #2309	Tung-Sol
7915	Q1	Transistor, Type 2N2924, Selected	Ballantine
7915	Q2	Transistor, Type 2N2924, Selected	Ballantine
7915	Q3	Transistor, Type 2N2924, Selected	Ballantine

*In some instruments the component listed may not be used at all or its value may differ from the value shown.

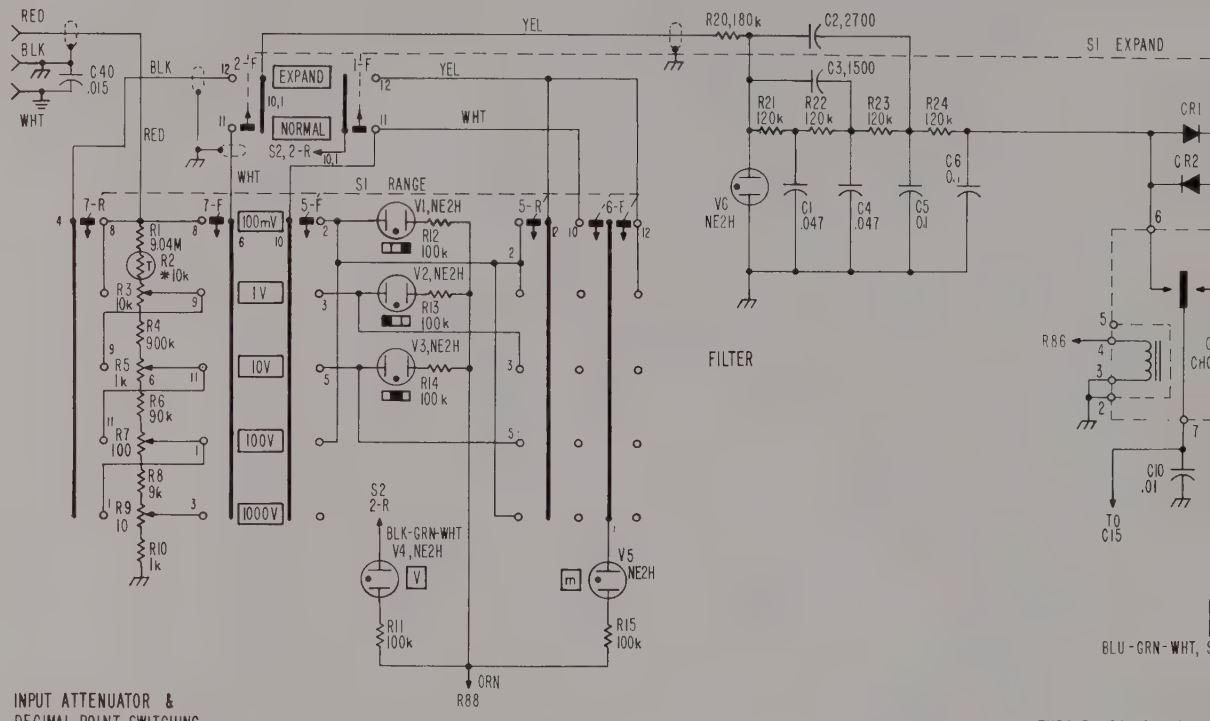
REPLACEMENT PARTS LIST (Continued)

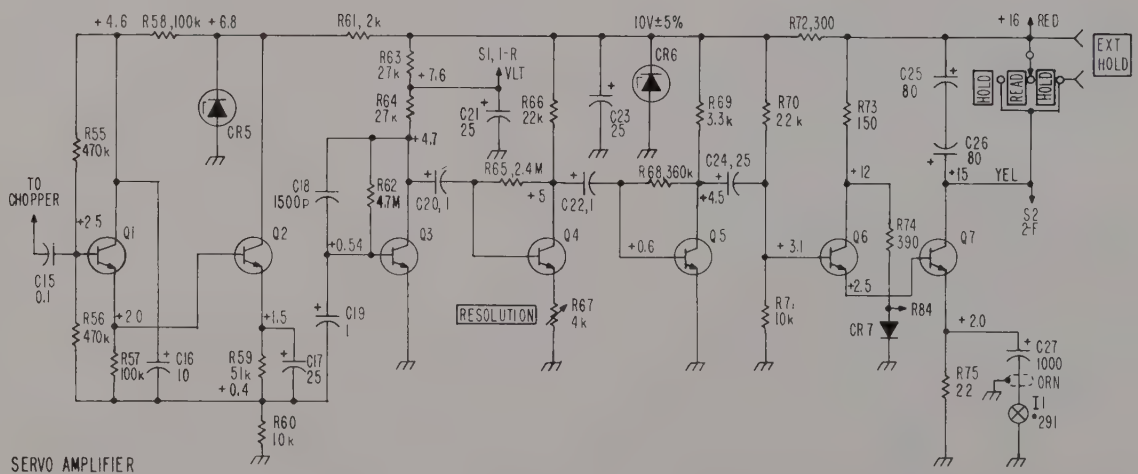
REFER TO MODEL 353 SCHEMATIC, DWG. ME-3270[illegible] N

B. L. Part No.	Circuit Symbol	Other Components	Manufacturer
7915	Q4	Transistor, Type 2N2924	General Electric
7915	Q5	Transistor, Type 2N2924	General Electric
7915	Q6	Transistor, Type 2N2924	General Electric
7930	Q7	Transistor, Silicon Power, Type 2N3766	Motorola
7915	Q8	Transistor, Type 2N2924	General Electric
7772	S1	Switch, Attenuator and Mode, Special	Ballantine
7761	S2	Switch, Input, Special	Ballantine
7758	S3	Switch, Toggle, On-Off-Momentary, Type 7107	C & K Components
6261	T1	Transformer, Power, Special	Ballantine
7917	V1	Tube, Type NE2H C2A	General Electric
7917	V2	Tube, Type NE2H C2A	General Electric
7917	V3	Tube, Type NE2H C2A	General Electric
7917	V4	Tube, Type NE2H C2A	General Electric
7917	V5	Tube, Type NE2H C2A	General Electric
7940	V6	Neon Lamp, Type NE81/5AG	General Electric
4161	—	AC Power Cord	Ballantine
8378	—	Expand Dial Link Chain, 10"	Bohannon Industries

8. MECHANICAL PARTS WHICH MAY REQUIRE REPLACEMENT

B. L. Part No.	Description	Consists of
8330	Counter Motor Assembly	1 Counter 1 Motor 1 Potentiometer Bracket 2 Illumination Lamps 1 47 Ω Resistor 1 Bracket (Counter Mounting) Part Nos. 8318, 8317 and 8316
8318	Counter Cover and Decimal Point Assembly	3 Neon Lamps 1 Board (Decimal Point) 3 Sleeves 1 Cover 1 Illumination Lamp
8317	Gear Assembly	1 Gear 2 Spring Spacers 4 Springs 4 Roll Pins 1 Bushing 1 Nylon Washer
8316	10 Turn Potentiometer Assembly	1 10 Turn Potentiometer 1 Sleeve 1 Ground Lug





CAPACITORS: NOT MARKED — MICROFARADS (10^{-6}F)
P — PICOFARADS (10^{-12}F)
RESISTORS: NOT MARKED — OHMS (Ω)
k — KILOHMS (10^{3}Ω)
M — MEGOHMS (10^{6}Ω)
VOLTAGE: NOT MARKED — VOLTS (V)
mV — MILLIVOLTS (10^{-3}V)

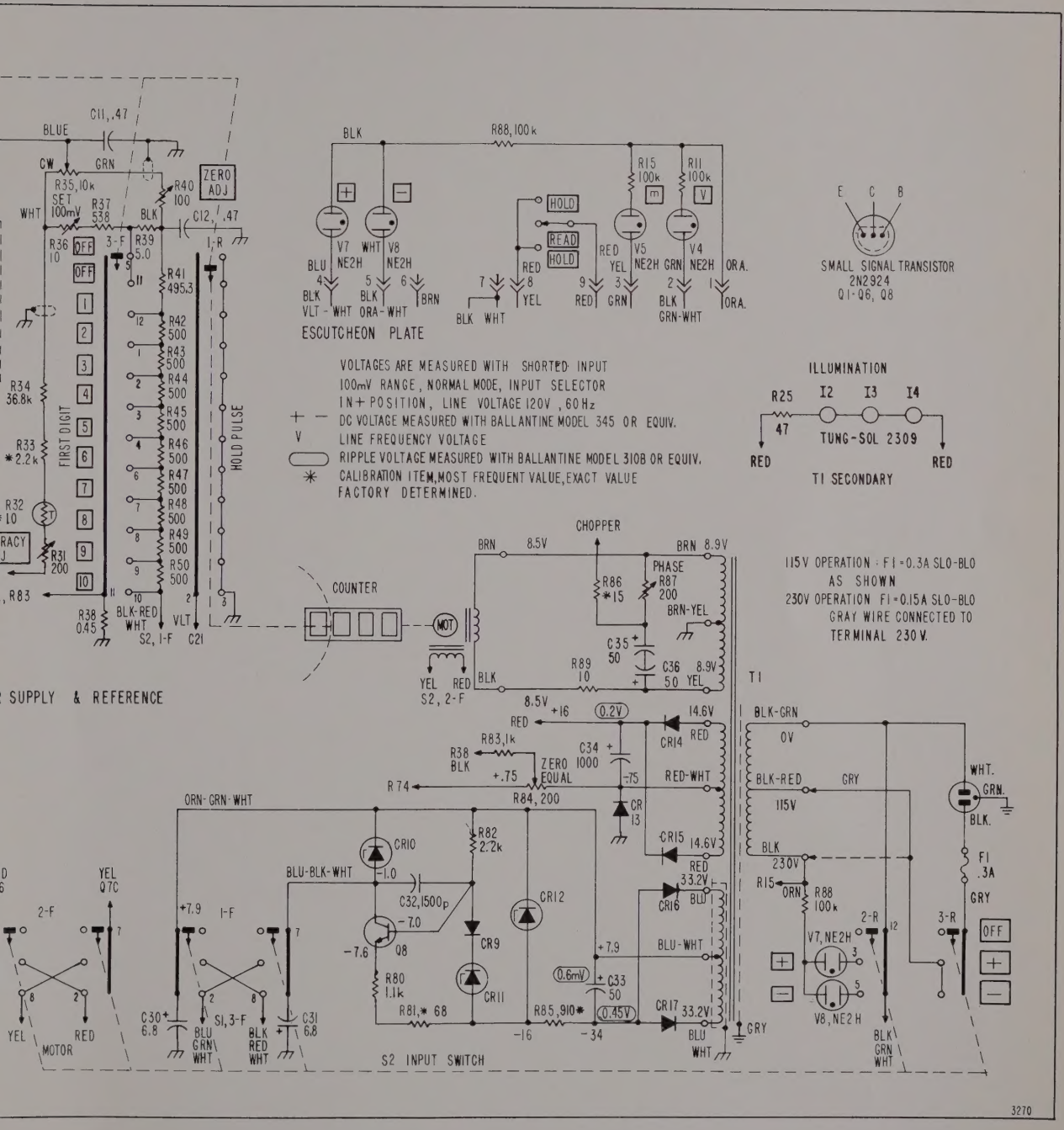


Figure 14. Schematic of Model 353, Dwg. 3270-MN

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